

Constructed wetlands

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Fantastic resource for water treatment issues

CNSTRUCTED WETLANDS

The system of planting aquatic plants such as reeds or bulrushes in a wet (often gravel) substrate medium for graywater recycling is called a "constructed wetland" or "artificial wetland." The first artificial wetlands were built in the 1970s. By the early 1990s, there were more than 150 constructed wetlands treating municipal and industrial wastewater in the US.

According to the US Environmental Protection Agency, "Constructed wetlands treatment systems can be established almost anywhere, including on lands with limited alternative uses. This can be done relatively simply where wastewater treatment is the only function sought. They can be built in natural settings, or they may entail extensive earthmoving, construction of impermeable barriers, or building of containment such as tanks or trenches. Wetland vegetation has been established and maintained on substrates ranging from gravel or mine spoils to clay or peat. . . . Some systems are set up to recharge at least a portion of the treated wastewater to underlying ground water. Others act as flow-through systems, discharging the final effluent to surface waters. Constructed wetlands have diverse applications and are found across the country and around the world. They can often be an environmentally acceptable, cost-effective treatment option, particularly for small communities."¹⁶

A wetland, by definition, must maintain a level of water near the surface of the ground for a long enough time each year to support the growth of aquatic vegetation. Marshes, bogs, and swamps are examples of naturally occurring wetlands. Constructed wetlands are designed especially for pollution control, and exist in locations where natural wetlands do not.

Two types of constructed wetlands are in common use today. One type exposes the water's surface (Surface Flow Wetland, Figure 9.6), and the other maintains the water surface below the level of the gravel (Subsurface Flow Wetland, Figures 9.4, 9.5, and 9.7). Some designs combine elements of both. Subsurface flow wetlands are also referred to as Vegetated Submerged Bed, Root Zone Method, Rock Reed Filter, Microbial Rock Filter, Hydrobotanical Method, Soil Filter Trench, Biological-Macrophytic Marsh Bed, and Reed Bed Treatment.¹⁷

Subsurface flow wetlands are considered to be advantageous compared to open surface wetlands, and are more commonly used for individual households. By keeping the water below the surface of the gravel medium, there is less chance of odors escaping, less human contact, less chance of mosquito breeding, and faster "treatment" of the water (due to more of the water being exposed to the microbially populated gravel surfaces and plant roots). The subsurface water is also less inclined to freeze during cold weather.

Constructed wetlands generally consist of one or more lined beds, or cells. The gravel media in the cells should be as uniform in size as possible and should consist of small to medium size gravel or stone, from one foot to three feet in depth. A layer of sand may be used either at the top or the bottom of a gravel medium, or a layer of mulch and topsoil may be applied over the top of the gravel. In some cases, gravel alone will be used with no sand, mulch, or topsoil. The sides of the wetlands are bermed to prevent rainwater from flowing into them, and the bottom may be slightly sloped to aid in the flow of graywater through the system. A constructed wetland for a household, once established, requires some maintenance, mainly the annual harvesting of the plants (which can be composted).

In any case, the roots of aquatic plants will spread through the gravel as the plants grow. The most common species of plants used in the wetlands are the cattails, bulrushes, sedges, and reeds. Graywater is filtered through the gravel, thereby keeping the growing environment wet, and bits of organic material from the graywater become trapped in the filtering medium. Typical retention times for graywater in a subsurface flow wetland system range from two to six days. During this time, the organic material is broken down and utilized by microorganisms living in the medium and on the roots of the plants. A wide range of organic materials can also be taken up directly by the plants themselves.

Bacteria, both aerobic and anaerobic, are among the most plentiful microorganisms in wetlands and are thought to provide the majority of the wastewater treatment. Microorganisms and plants seem to work together symbiotically in constructed wetlands, as the population of microorganisms is much higher in the root areas of the plants than in the gravel alone. Dissolved organic materials are taken up by the roots of the plants, while oxygen and food are supplied to the underwater microorganisms through the same root system.¹⁸

Aquatic microorganisms have been reported to metabolize a wide range of organic contaminants in wastewater, including benzene, naphthalene, toluene, chlorinated aromatics, petroleum hydrocarbons, and pesticides. Aquatic plants can take up, and sometimes metabolize, water contaminants such as insecticides and benzene. The water hyacinth, for example, can remove phenols, algae, fecal coliforms, suspended particles, and heavy metals including lead, mercury, silver, nickel, cobalt, and cadmium from contaminated water. In the absence of heavy metals or toxins, water hyacinths can be harvested as a high-protein livestock feed. It can also be harvested as a feedstock for methane production. Reed-based wetlands can remove a wide range of toxic organic pollutants.¹⁹ Duckweeds also remove organic and inorganic contaminants from water, especially nitrogen and phosphorous.²⁰

When the outdoor air temperature drops below a certain point (during the winter months in cold climates), wetland plants will die and microbial activity will drop off. Therefore, constructed wetlands will not provide the same level of water treatment year round. Artificial wetlands systems constitute a relatively new approach to water purification, and the effects of variables such as temperature fluctuations are not completely understood. Nevertheless, wetlands are reported to perform many treatment functions efficiently in winter. One source reports that the removal rates of many contaminants are unaffected by water temperature, adding, "The first two years of operation of a system in Norway showed a winter performance almost at the same level as the summer performance." Some techniques have been developed to insulate wetland systems during the colder months. For example, in Canada, water levels in wetlands were raised during freezing periods, then lowered after a layer of ice had formed. The cattails held the ice in place, creating an air space over the water. Snow collected on top of the ice, further insulating the water underneath.²¹

It is estimated that one cubic foot of artificial wetland is required for every gallon per day of graywater produced. For an average

single bedroom house, this amounts to about a 120 square foot system, one foot deep. However, it is better to overbuild a system than to underbuild. Some constructed wetland situations may not have enough drainage water from a residence to keep the system wet enough. In this case, extra water may be added from rain water collection or other sources.

WETLAND PLANTS

Aquatic plants used in constructed wetland systems can be divided into two general groups: microscopic and macroscopic. Most of the microscopic plants are algae, which can be either single cell (such as *Chlorella* or *Euglena*) or filamentous (such as *Spirulina* or *Spyrogyra*).

Macroscopic (larger) plants can grow under water (submergent) or above water (emergent). Some grow partially submerged and some partially emerged. Some examples of macroscopic aquatic plants are reeds, bulrushes, water hyacinths, and duckweeds (see Figure 9.8 and Table 9.1). Submerged plants can remove nutrients from wastewaters, but are best suited in water where there is plenty of oxygen (water with a high level of organic material tends to be low in oxygen due to extensive microbial activity).

Examples of floating plants are duckweeds and water hyacinths. Duckweeds can absorb large quantities of nutrients. Small ponds that are overloaded with nutrients such as farm fertilizer run-off can often be seen choked with duckweed, appearing as a green carpet on the pond's surface. In a two and a half acre pond, duckweed can absorb the nitrogen, phosphorous, and potassium from the excretions of 207 dairy cows. The duckweed can eventually be harvested, dried, and fed back to the livestock as a protein-rich feed. Livestock can even eat the plants directly from a water trough.²²

Algae work in partnership with bacteria in aquatic systems. Bacteria break down complex nitrogen compounds and thereby make the nitrogen available to algae. Bacteria also produce carbon dioxide which is utilized by the algae.²³

SOILBOXES OR SOILBEDS

A soilbox is a box designed to allow graywater to filter through it while plants grow on top of it (Figure 9.14). Such boxes have been in use since the 1970s. Since the box must be well-drained, it is first layered with rocks, pea gravel, or other drainage material. This is covered with screening, then a layer of coarse sand is added, followed by finer sand; two feet of top soil is added to finish it off. Soilboxes can be located indoors or outdoors, either in a greenhouse, or as part of a raised-bed garden system.²⁴ Soilboxes (soilbeds) located in indoor greenhouses are illustrated in Figures 9.11 and 9.13. An outdoor soilbed is illustrated in Figure 9.12.

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